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Research Article

Comparative In-vitro Efficacy of Selected Fungicides and Plant Extracts for the sustainable management of Sugarcane Red Rot Caused by *Colletotrichum falcatum*

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ABSTRACT

Sugarcane (*Saccharum officinarum* L.) is one of the economically valuable crops grown worldwide, but its production is severely affected by red rot caused by Colletotrichum falcatum. Therefore, the present study evaluates integrative approaches for the management of *Colletotrichum falcatum*. In this study, five fungicides, and five botanical extracts were tested against *C. falcatum* under in-vitro conditions using the poisoned food technique in a Completely Randomized Design (CRD) with three replications. According to results, chemical treatments, Propineb + Iprovalicarb, Pyraclostrobin + Metiram, and Thiophanate methyl at 300 ppm almost completely inhibited mycelial growth, while garlic extract at 15% was the most potent botanical, completely suppressing fungal growth. These findings demonstrate that effective fungicides, and potent plant extracts can significantly reduce *C. falcatum* growth, suggesting their potential use in integrated and sustainable management of red rot in sugarcane.

Keywords: Sugarcane Diseases*; Colletotrichum falcatum;* Fungicides; Botanical extracts; Management*.*

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is one of the economically valuable crops grown globally in tropical and subtropical regions as a primary source of sugar and raw material for agro-based industries. According to FAO Stat (2024-2025), sugarcane was cultivated on an area of 26.71 million hectares globally, yielding a total production of 1,940.65 million tons. In comparison, Pakistan contributed 87.67 million tons of production from an area of 1.32 million hectares. There are multiple living and non-living factors that affect the cultivation of sugarcane across the globe (Malathi et al., 2011; Balendres 2025). Sugarcane is affected by over 200 diseases caused by fungi, viruses, nematodes, bacteria, and phytoplasmas. Among them red rot disease caused by *Colletotrichum falcatum* is considered as one of the most destructive diseases (silva et al. 2024: sameera 2023). The disease is often referred to as the “cancer” of sugarcane because of its aggressive nature and its capacity to severely reduce both cane yield and sugar recovery. This disease poses a serious threat to sugarcane yield and quality (Von Arx & Müller, 1954; Rani et al. 2025).

Red rot disease causes huge economic damage and losses in productivity in every region of world and is transmitted by infected planting material, irrigation water, soil and insect damage (Putra & Damayanti 2012; Yin et al. 2025).

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Typical symptoms include reddening of internal tissues, drying of leaves, and formation of dark fungal structures inside the stalk (Olahan et al., 2020; Nisar et al. 2024). Losses due to this disease can change considerably based on the environmental factors and susceptibility of the cultivar to the disease, but significant losses in cane weight and level of sugar content have been reported in most areas.

Management of red rot remains difficult because the pathogen survives in plant debris and soil for long periods. Traditional methods such as using resistant varieties, cultural control and use of chemical fungicides can control the disease but use of excessive chemicals may damage the environment. Safer alternatives, like plant extracts, offer promising ways to reduce fungal growth naturally (poudel et al. 2022; Viswanathan 2025).

MATERIALS AND METHODS

Collection and multiplication of fungal pathogens

The culture of red rot fungus (*Colletotrichum falcatum*) was obtained from the Biological control Biopesticide Research Laboratory, Department of Plant Pathology, Faculty of Crop Protection, Sindh Agriculture University, Tandojam. The culture was purified and maintained on potato dextrose agar (PDA).

Evaluations of fungicides

The in-vitro efficacy of different fungicides was evaluated using the poisoned food technique. PDA medium was prepared, and fungicides were mixed into it at concentrations of 100, 200, and 300 ppm. About 20 ml of the medium was poured into sterile Petri plates (90 mm) and allowed to solidify. Fungal discs from 8–10-day-old cultures of *C. falcatum* were placed at the center of each plate. PDA plates without fungicides used as the control. All plates were sealed with parafilm and incubated at 25 °C for seven days. Mycelial growth was recorded at 48-hour intervals, and each treatment was replicated three times.

Evaluation of botanical extracts

Fresh plant materials of moringa, neem, ginger, garlic and chili leaves were blended with 100 ml sterilized water. The mixture was filtered through the two layered sterilized muslin cloth and added to PDA at 5, 10 and 15% concentrations. The plates were inoculated with fungal discs and incubated at 28 °C. Plates without any plant extract were kept as controls. Observations on the fungal mycelial growth and the inhibition zones formed by the plant extracts were recorded every 48 hours for up to seven days after inoculation.

Data analysis

The collected data were analyzed using Analysis of Variance (ANOVA) with Statistix v. 8.1 software. Significant differences between treatment means were determined using the Least Significant Difference (LSD) test at a 5% probability level.

RESULTS

In-vitro effect of the various fungicides on the average mycelial growth of *Colletotrichum falcatum* Went

All fungicides reduced fungal growth compared with the control, and their effectiveness increased with concentration. At 300 ppm concentration, all fungicides showed high inhibitory effects on the average mycelial growth of *C. falcatum* mycelial growth. Propineb + Iprovalicarb, Pyraclostrobin + Metiram and Thiophanate methyl were the most effective treatments with the lowest average mycelial growth of 0.8 mm. Tebuconazole + Trifloxystrobin was also found to be highly effective with a colony diameter of 0.9 mm and Fosetyl-Aluminium was also found to be slightly less effective with a colony growth of 1.1 mm. Tebuconazole + Trifloxystrobin were found to be most effective at 200 ppm, inhibiting mycelial growth of *C. falcatum* by 1.5 mm, followed by Pyraclostrobin + Metiram and Propineb + Iprovalicarb limiting the mycelial growth to 3.9 mm and 4.1 mm respectively. Fosetyl-Aluminium showed moderate antifungal activity, with 7.8 mm of mycelial growth compared to Thiophanate methyl, which recorded the 13.3 mm colony diameter.

However, at 100 ppm Tebuconazole + Trifloxystrobin still remained on top having minimal growth at 3.0 mm, Pyraclostrobin + Metiram next with 5.3 mm growth with moderate control. Moderate inhibition was observed with Propineb + Iprovalicarb and Fosetyl-Aluminium which recorded 8.4mm and 8.7mm growth of fungi, respectively. Meanwhile, Thiophanate methyl had little effect, with a colony diameter of 23.1 mm, almost equal to the control (Figure 1).

In-vitro effect of various botanical extracts on the average mycelial growth of the *Colletotrichum falcatum* Went

Botanical extracts significantly suppressed fungal growth at all tested concentrations. Garlic extract had the best effect at the highest concentrations (15%) and was able to suppress the average mycelial growth completely (0.00

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mm), followed by neem extract (1.76 mm), moringa extract (2.97 mm), and ginger extract (5.31 mm). However, chilli leaf extract and ginger extract showed a relatively lower inhibition at the same concentration with a radial growth of 5.19 and 5.31 mm respectively. At the intermediate concentration (10%), a similar trend was observed. Garlic extract exhibited the highest inhibitory activity, limiting the average mycelial growth of *C. falcatum* to 0.26 mm, followed by neem (2.48 mm) and moringa (4.20 mm). Chili leaf extract (6.62 mm) and ginger (8.67 mm) showed moderate levels of inhibition at this concentration. The inhibitory effects of the botanical extracts were relatively lower but still noticeable at the lowest concentration (5%). Garlic extract was the most effective showing, followed by neem (2.64 mm), moringa (5.69 mm) and chilli leaf extract (9.28 mm). Ginger extract had the lowest inhibition at this dose, its colony diameter was 20.98 mm (Figure 2).

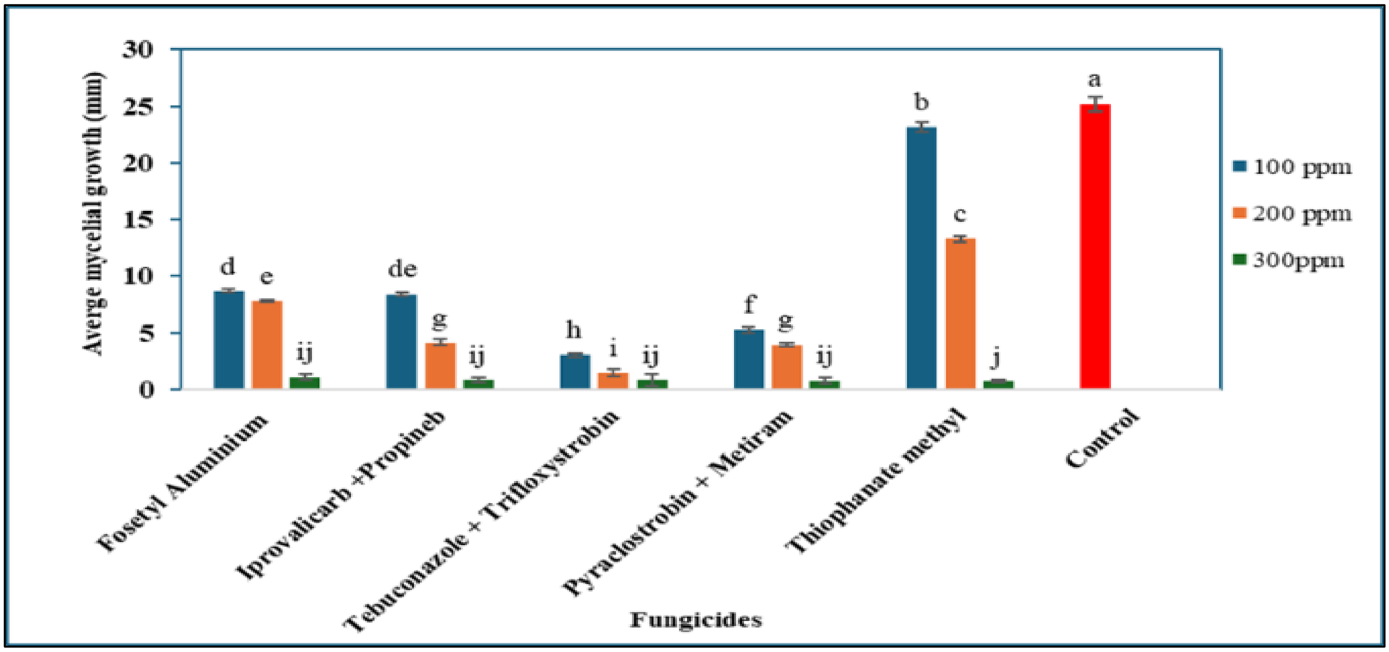

Figure 1. Effect of the various fungicides on the average mycelial growth of Colletotrichum falcatum Went.
*Letters over the bars are indicating significant difference at LSD = 0.7270 and p = 0.0000.

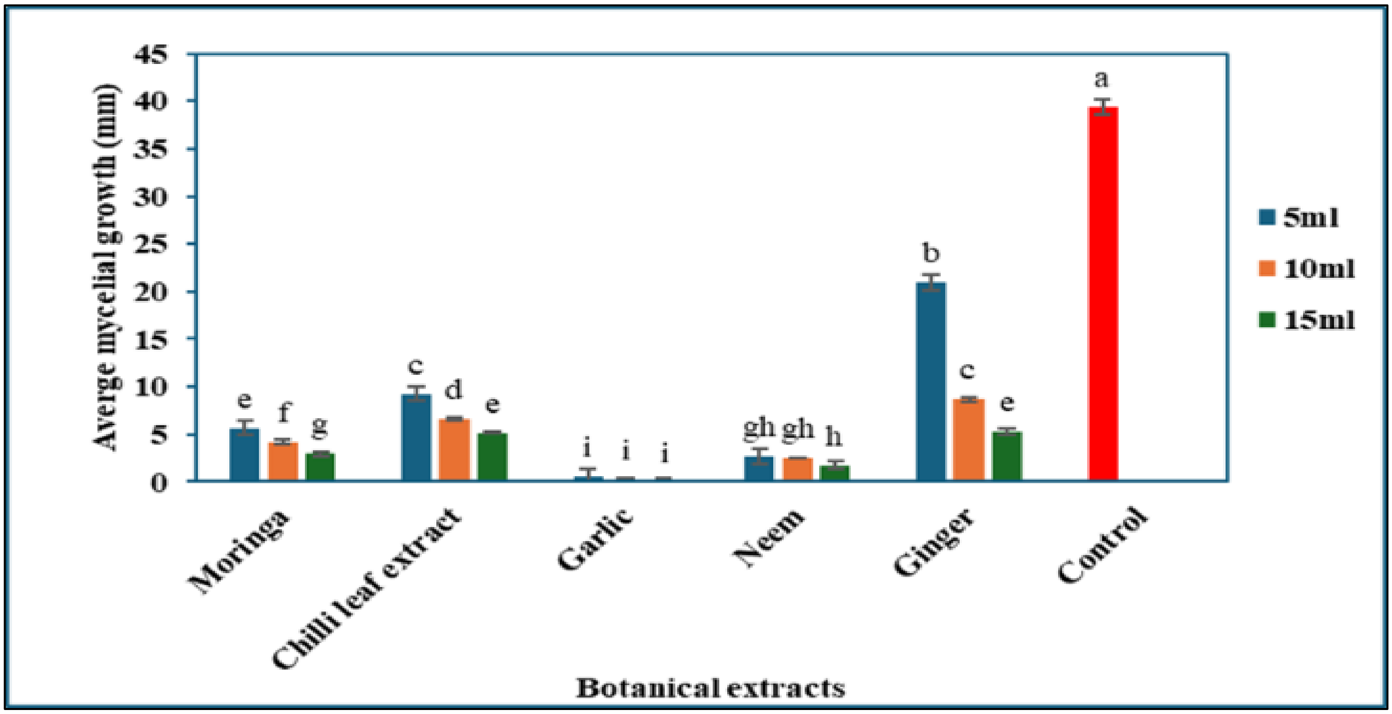

Figure 2. Effect of the botanical extracts on the average mycelial growth of Colletotrichum falcatum Went.
*Letters over the bars are indicating significant difference at LSD = 0.7270 and p = 0.0000.

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DISCUSSION

The current research was conducted to evaluate the *in-vitro* effectiveness of various fungicides and botanical extracts against *Colletotrichum falcatum*. The findings clearly showed a significant difference among the treatments, exhibited significant *in-vitro* ability to inhibit the mycelial development of the pathogen.

The results of the fungicidal treatments showed that the growth of *C. falcatum* was inhibited by all the fungicides used at different concentrations. At 300 ppm, Propineb + Iprovalicarb, pyraclostribin + Metiaram and Thiophanate methyl had almost complete inhibition of mycelial growth recorded (0.8 mm). While, Tebuconazole + Trifloxystrobin was also highly effective (0.9 mm). In comparison, the control treatment showed the largest mycelial diameter (25.2 mm).

These results align with the findings of Abbas et al. (2016) and Bhanuprasad et al. (2020), who reported that systemic fungicides such as carbendazim, mancozeb, and triazole-based combinations effectively suppress *C. falcatum* under laboratory and field conditions.

The antifungal activity of various plant extracts was assessed and it was found that garlic extract had the most potent antifungal activity among all the botanicals tested and their effectiveness in growth inhibition of *C. falcatum* was complete (0.00 mm) with a concentration of 15 %. Neem and moringa extracts were followed with extensive inhibitory activity (1.76 mm and 2.97 mm, respectively).

These results are in good agreement with Shinwari (2010) and Nasir et al. (2014), who highlighted the role of plant-derived compounds (particularly, organosulphur and phenolic constituents) in the inhibition of fungal pathogens. The strongest antifungal effect of garlic may be due to the presence of allicin, a sulfur-containing compound which interferes with fungal enzymatic systems and membrane activity. Neem extract, on the other hand, contains azadirachtin and related triterpenoids which have been known to inhibit spore germination and hyphal growth.

The results indicate the efficacy of different fungicides, and some botanical extracts in exhibiting strong antifungal activity against *C. falcatum*. While chemical fungicides showed almost complete inhibition under laboratory conditions, and botanicals are safer and more sustainable as well as providing integrated disease management. The variation in efficacy among treatments is due to the modes of action of the treatments, which include direct toxicity (chemicals), and plant extracts (secondary metabolites).

CONCLUSION

The present study demonstrated that both chemical fungicides and botanical extracts possess significant inhibitory effects against *Colletotrichum falcatum,* the causal agent of red rot of sugarcane. All tested fungicides effectively suppressed fungal growth, with propineb + Iprovalicarb, Pyraclostrobin + Metiaram, and thiophanate methyle showing almost complete inhibition at higher concentration *in-vitro* conditions. among the botanical treatments, garlic extract exhibited the highest antifungal activity, completely inhabiting the mycelial growth of *C. falcatum* at the highest concentration, followed by neem and moringa extracts. These results confirm the strong antifungal potential of chemical fungicides and botanical extracts for the effective management of the pathogen.

Overall, the findings suggest that while chemical fungicides give rapid and effective suppression of the pathogen, botanical extracts represent environmentally safe and sustainable alternative. Therefore, integrating effective fungicides with plant-based extracts may provide a promising strategy for the sustainable management of red rot disease in sugarcane.

AUTHOR CONTRIBUTIONS

MAS Research and Data collection, laboratory processing, experiment conducting GHJ. Research concept and research supervisor, SK, data collection. MAA. Finalized manuscript and research Co supervisor, JDH revised manuscript and research Co supervisor, AAG – English proof reading and research Co supervisor, NS. Data collection and laboratory processing ARK. Data collection and laboratory processing.

COMPETING OF INTEREST

The authors declare no competing interests.

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